FSCH/FSPT Registration Quiz 2024 Results V1.0

Information:

Unlike stated in FSCH Handbook 2024 CH 2.1.3, protest time ends 4 hours later, meaning 2024-01-27 17:00 CET.
Send your protest(s) to geral@formulastudent.pt irrelevant of your intended participation in FSCH, FSPT or both.

Q1 (CV & EV)

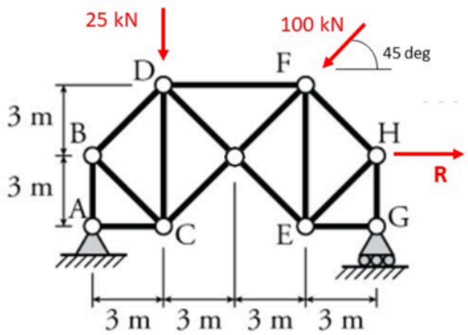
A chocolate manufacturer is producing a new type of chocolate bar with a special formulation. The chocolate is initially melted and poured into a mould at a temperature of 50°C. The chocolate bar is then left to cool in a room with a constant temperature of 20°C. The manufacturer wants to determine the time it takes for the chocolate to cool down to a safe handling temperature of 30°C.
Given that the chocolate follows Newton's Law of Cooling, the manufacturer has conducted preliminary experiments and determined that the cooling rate constant (k) for this chocolate formulation is 0.02 per minute.
Determine the time it takes for the chocolate to cool down from 50°C to 30°C.
Answer in min and provide the value with 2 decimal places, e.g. 12.34.

Answer: 54.93

Newton's Law of Cooling: dTdt=k(T-T amb)
T amb=20°C
so T(t) = 20 + 30e-0.02t
solving for t with T(t)=30°C gives t = - ln(13)0.02 = 54.93 min

Q2 (CV & EV)

Knowing that the member AC is under a force of -25 kN, what is the force in the element HG? Force R is an unknown horizontal force applied on point H.
Answer in kN and provide the value with 1 decimal place, e.g. 12.3.
Follow the sign convention "-" for a compressive force and "+" for tensile, e.g. -12.3 or 12.3.



Answer: -35.4

Assuming positive x from left to right and positive y from down to up (coordinate system not relevant for solution)
R_A_x (x component of reactive force at A) = -f_AC = 25 kN
Sum of forces along x:
R_A_x = sin(45)*100 kN - R => R = 45.71068 kN
Sum of moments around A
R_G_y * 12 = 25 * 3 + R * 3 + 100 * sin(45) *3 - 100 * cos(45) *2 => R_G_y = 35.355 kN
R_G_y = - f_HG => f_HG = -35.355 kN

Q3 (CV & EV)

Your racecar is equipped with four independent suspensions. The front and rear motion ratios are 0.8 and 0.75, respectively. The front and rear spring stiffnesses are 16 N/mm and 18 N/mm, respectively. The tire stiffness is 75 N/mm. Under an aerodynamic load applied at the vehicle centre of gravity, the wheel travel relative to a static position is the same for the 4 wheels. What is the static longitudinal weight distribution of the car? (Assume that the vehicle is coasting, i.e., no longitudinal force is applied by the wheels on the ground).

Answer as % of mass on the front axle and provide the value with 1 decimal place, e.g. 12.3.

Answer: 43.9

Front wheel rate = Front spring stiffness / front motion ratio = 16 / 0.8 ^ 2 = 25 N/mm
Rear wheel rate = Rear spring stiffness / rear motion ratio = 18 / 0.75 ^ 2 = 32 N/mm

$$Downforce * \frac{fraction\ weight\ front}{Front\ wheel\ rate} = Downforce * \frac{fraction\ weight\ rear}{Rear\ wheel\ rate}$$

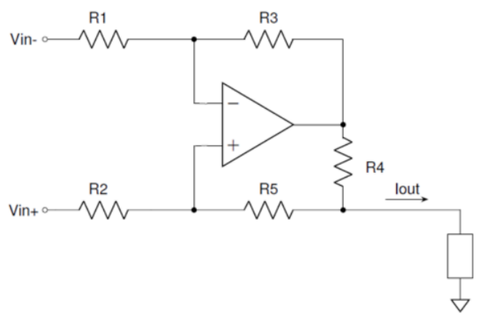
$$\Leftrightarrow \quad \frac{fraction\ weight\ front}{1-fraction\ weight\ front} = \frac{25}{32}$$

$$\Leftrightarrow \quad fraction\ weight\ front = 43.9\ \%$$

Note that the drag force does not cause any longitudinal mass transfer since it is not balanced by an equal and opposite force applied in the tires, i.e., the drag force causes deceleration of the vehicle instead of mass transfer.

Q4 (CV & EV)

The figure below depicts an Improved Howland Current Pump circuit. Assume that Vin- is connected to ground, 0 V, and Vin+ is 5 V. For R1 = R2 = R3 = 1 kΩ and R4 = 100 Ω, compute the magnitude of the output current Iout.



Answer in mA and provide the value with 1 decimal place, e.g. 12.3.

Answer: 50.0

Formulas for an improved howland pump circuit:

$Iout = (G \times (Vin+ \ - \ Vin-))/R4,$

$G = R3/R1; \quad R3/R1 = (R5 + R4)/R3$

$G = 1k/1k = 1; \ 1 = (R5 + R4)/R3 \ <=> R5 = 1000 - 100 = 900\ \Omega$

$Iout = 1 * (5 - 0)/100 = 0.05\ A = 50.0\ mA$

Q5 (CV & EV)

A structural engineer needs to design a thin simply supported rectangular beam that experiences a point load of 500N in the middle of its length. The beam is 200mm long and 50mm wide. The engineer considers two materials for the panel: aluminium and quasi-isotropic carbon fibre. The aluminium used has a Young's Modulus of 70GPa and a density of 2.7 g/cm^3. The composite used has a Young's Modulus of 220 GPa and a density of 1.26 g/cm^3. The environmental impact of the beam aluminium used is 8 kgCO2 per kilo of aluminium and the one of the carbon is 26 kgCO2 per kilo of composite.
What is the lowest possible CO2 emission out of these two options while having a beam maximum deflection of 3 mm.
a) Aluminium
b) Composite
Answer in kgCO2 and provide the value with 3 decimal places, e.g. 12.345.

Answer: 0.986

$$Deflection: \frac{500 * 200^3}{48\,EI}$$

$$Inertia: I = \frac{50\,t^3}{12}$$

So $t > \sqrt[3]{\frac{500 * 12}{3 * 48 * 50 * E}} * 200$

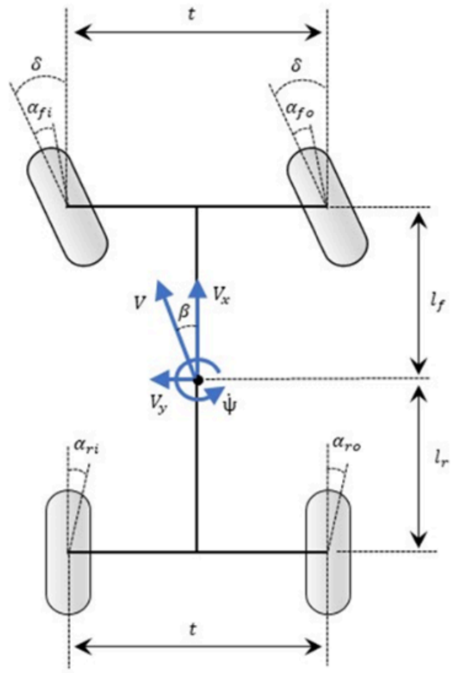
Aluminium: t = 4.56 mm → mass = (4.56*200*50)*2.7e-3 = 123.12 g so the environmental impact is: 8e-3 * 123.12 = 0.986 kgCO2
Composite: t = 3.12 mm → mass = (3.12*200*50)*1.26e-3 = 39.31 g so the environmental impact is: 26e-3 * 39.31 = 1.022 kgCO2

Q6 (CV & EV)

Your racecar is performing a steady-state corner with 8 metres radius at a speed of 10.2 m/s. The vehicle has a longitudinal weight distribution of 50% front / 50% rear, parallel steering (0% ackermann), and 0.5 degrees rear wheel toe in. Knowing that the slip angle of the rear inside wheel is 4.6 degrees, how much toe is needed on the front wheels to ensure that these have equal slip angles ($\alpha_{fi} = \alpha_{fo}$)?

l_f = 0.8 m, l_r = 0.8m, t = 1.2 m, δ = 12 deg

Toe in is considered positive, toe out is considered negative. Answer in deg and provide the value with 1 decimal place, e.g. 12.3.



Answer: -0.5

Assuming x is positive from rear to front and y is positive from right to left (coordinate system not relevant for solution)
Yaw_rate = velocity/radius = 10.2 / 8 = 1.275 rad/s
Vx_RI = Vx - Yaw_rate*t/2 = 9.435 m/s
Vy_RI = -tan(alfa_RI + toe_rear)*Vx_RI = -tan(5.1 deg)*9.435 = 0.84205 m/s
Vx_FI = Vx_RI = 9.435 m/s
Vy_FI = Vy_RI + Yaw_rate * (lr+lf) = -tan(5.1 deg)*9.435 + 1.275*1.6 = 1.19795 m/s
alfa_FI = 12 - atan(1.19795/9.435) - toe_front = 4.76 - toe_front
Vx_FO = Vx + Yaw_rate*t/2 = 10.965 m/s
Vy_FO = Vy_FI = 1.19795 m/s
alfa_FO = 12 - atan(1.19795/10.965) + toe_front = 5.76 + toe_front
alfa_FI = alfa_FO => toe_front = - 0.5 deg

Q7 (CV & EV)

Last year's car had a sprocket on the output shaft of the engine with 16 teeth. Connected to this sprocket was a chain that drove the output gear resulting in a gear ratio of 2.5. This year, the team wants to maintain the same sprocket but in the meanwhile the supplier has discontinued the previously used output gear and the closest one in stock has 2 extra teeth. What is the new gear ratio if the team chooses to use it?

Answer is unitless, provide the value with 1 decimal place, e.g. 12.3.

Answer: 2.6

Old car : Z1= 16; i1/2= 2,5
New car: Z1=Z3=16; Z4=Z2+2

Z2= Z1*i1/2
Z2= 16*2,5
Z2= 40

Z4= Z2+2
Z4= 40+2
Z4= 42

i3/4= Z4/Z3
i3/4= 42/16
i3/4= 2,625 → 2,6

Q8 (CV & EV)

From these options, what is the lightest possible section for the Main Hoop Bracing?

- ◯ Round tube Outer diameter = 25 mm, thickness = 1.2 mm
- ◯ Round tube Outer diameter = 20 mm, thickness = 1.5 mm
- ◯ Squared tube side = 1", thickness = 3/64"
- ◯ Round tube Outer diameter = 32 mm, thickness = 1.2 mm
- ✖ Squared tube side = 7/8 ", thickness = 1/16"
- ◯ Round tube Outer diameter = 28 mm, thickness = 1.6 mm

Option 1, 2, 3 & 4 → not enough inertia or too thin
Squared tube 7/8" x 1/16" → (25,4 x 7/8)^2 mm2 - (25,4 x 7/8 - 2x(25.4 × 1/16))^2 mm2 = 131.0 mm2
Rounded tube 28 x 1.6 → 25,4^2 mm2 - (25,4 - 2(25.4 × 3/64))^2 mm2 = 132.7 mm2

Q9 (CV & EV)

Compute the energy retrieved from a 2F supercapacitor charged to 100V and discharged at constant current down to 50V?

- ✖ 7.5 kJ
- ○ 10 kJ
- ○ All wrong
- ○ 5 kJ
- ○ 2.5 kJ
- ○ 3.75 kJ

$$E = 0.5 * C * (Vinitial^2 - Vfinal^2)$$

$$E = 0.5 * 2 * (100^2 - 50^2) = 0.5 * 2 * (100000 - 2500) = 1 * (7500) = 7.5\,kJ$$

Q10 (CV)

What is the vibration frequency of a four-cylinder in-line engine at 4500 rpm at the dominant engine order that causes the typical four-cylinder hum?

Answer in Hz and provide the value with 0 decimal places, e.g. 12.

Answer: 150

"In the widely used four-cylinder in-line engines, the vibrations of the second engine order are dominant; this engine design owes the typical four-cylinder hum to them." [Entkopplungselemente in der Fahrzeugtechnik] → nOrd=2 (It can also be found on the internet.)
f= nOrd*r*Hz/(60*1/min)
f= 2*4500*(1/min)*Hz/(60*(1/min))
f= 9000 Hz/60
f= 150 Hz

Q11 (CV)

Which statement is right?

- ○ Only fuel lines which are rated for temperatures of maximum of 120 °C are allowed to use between fuel tank and fuel rail and return lines.
- ○ Only fuel lines which are rated for temperatures of at least 100 °C are allowed to use between fuel tank and fuel rail and return lines.
- ○ Fuel lines designed for temperatures of at least 120 °C may only be used between the fuel tank and the fuel distributor.
- ○ Fuel lines designed for temperatures of at least 200 °C may only be used between the fuel tank and the fuel distributor.
- ✖ Only fuel lines which are rated for temperatures of at least 120 °C are allowed to use between fuel tank and fuel rail and return lines.

CV 2.4.1

Q12 (CV)

Racing engines (for motorsports) often run at high mean piston speed and high compression ratio (i.e. high bmep), trading low engine displacement and weight for high wear and low Mean Time Between Failures. Consider a naturally aspirated 4-stroke engine to deliver 65 kW at 8,400 rpm with a mean piston speed of 18 m/s, a bmep of 12 atm, and 3 cylinders. Find the appropriate cylinder bore diameter for such an engine, in mm.

Consider 1 atm=101325 Pa.

Answer in mm and provide the value with 1 decimal place, e.g. 12.3.

Answer: 71.0

$$V_d = \frac{W_b}{bmep} = \frac{2\dot{W}_b}{N \cdot bmep} = \frac{2\left(65{,}000\,{}^{\mathrm{J}}/_{\mathrm{s}}\right)\left(60\,{}^{\mathrm{s}}/_{\mathrm{min}}\right)}{(8400\ \mathrm{rpm})(12\ \mathrm{atm})\left(101{,}325\,{}^{\mathrm{J}}/_{\mathrm{m^3\cdot atm}}\right)}$$

$$= 0.764 \times 10^{-3}\mathrm{m}^3$$

$$S = \frac{\bar{U}_p}{2N} = \frac{\left(18\,{}^{\mathrm{m}}/_{\mathrm{s}}\right)\left(60\,{}^{\mathrm{s}}/_{\mathrm{min}}\right)}{2(8400\ \mathrm{rpm})} = 0.0643\ \mathrm{m}$$

$$B = \left(\frac{4V_d}{n_c \pi S}\right)^{1/2} = \left[\frac{4(0.764\times 10^{-3}\mathrm{m}^3)}{3\pi(0.0643\ \mathrm{m})}\right]^{1/2} = 0.0710\ \mathrm{m} = 71.0\ \mathrm{mm}$$

Q10 (EV)

You have a battery in a 27s1p configuration, where each cell has a capacity of 15 Ah and 4.2 V maximum voltage. The cell discharge circuit uses a constant current of 500 mA to discharge individual cells when balancing is required. Your battery has currently an unbalance of 5% SoC between the highest and lowest SoC cells. You want to perfectly balance your battery so that the difference between the highest and lowest cells is 0V / 0% SoC. How much time will balancing take?

Answer in hours and provide the value with 1 decimal place, e.g. 12.3.

Answer: 1.5

Divide the charge difference by the current: 5% x 15 Ah / 0.5A = 1.5 h

Q11 (EV)

This year you want to double your accumulator voltage to match your new high voltage electrical motor. Assume you keep the same accumulator nominal energy and the same cells you used last year and change only the cell configuration (series/parallel). Complete the statement: For the same power profile at the battery output, the power dissipated in the new accumulator internal resistance is (………) the previous accumulator.

- four times
- double
- ✖ equal to
- half
- one fourth

Cells - Ecell (cell nominal energy), Vcell (cell nominal voltage), Rcell (cell internal resistance)

Battery old - Eold (old battery nominal energy), Vold (old battery total nominal voltage), Rold (old battery total internal resistance), (Sold)s(Pold)p (old battery series parallel configuration), Presold (old battery dissipated power in internal resistance)

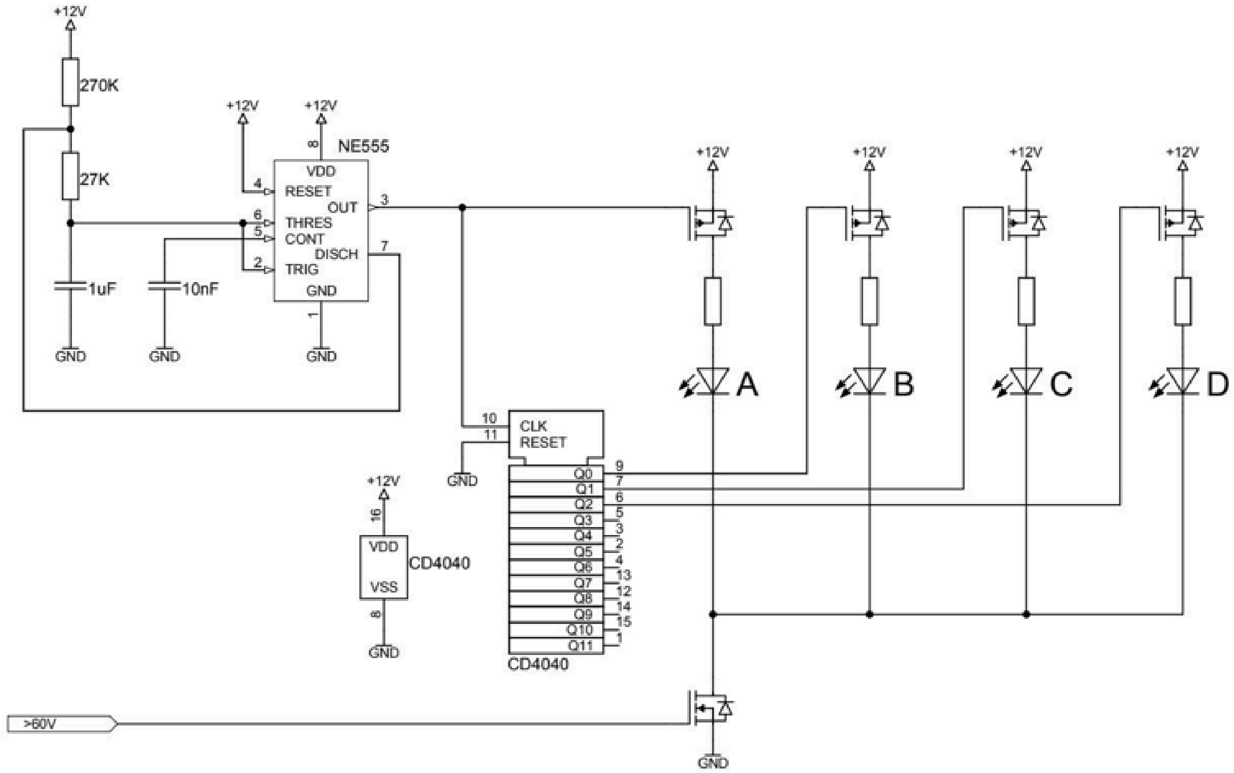
Battery new - Enew (new battery nominal energy), Vnew (new battery total nominal voltage), Rnew (new battery total internal resistance), (Snew)s(Pnew)p (new battery series parallel configuration), Presnew (new battery dissipated power in internal resistance)

Power profile - Ppro (RMS power), Ipro (RMS current)

We want Vnew = 2*Vold => **Snew = 2*Sold** (eqA)
To keep Enew = Eold => Sold * Pold = Snew * Pnew (eqB)
From A and B we get **Pnew = Pold/2** (eqC)
Rold = Rcell * Sold / Pold (eqD)
Rnew = Rcell * Snew / Pnew (eqE)
From A, B and E we get Rnew = Rcell * 2*Sold / (Pod/2) = Rcel * 4 * Sold/Pold => **Rnew = 4*Rold**
Ipro = Ppro / Vbat
Iproold = Ppro / Vold
Ipronew = Ppro / Vnew = Ppro / (2*Vold) => **Ipronew = ½ * Iproold**
Pres = Rbat * Ipro^2
Presold = Rold * Iproold
Presnew = Rnew * Ipronew = 4*Rold * (½ * Iprold)^2 =>
=> <u>**Presnew = Presold**</u>

Q12 (EV)

Your task is the design of the control circuit for the TSAL. Which of the LEDs in the circuit shown can be used as the red TSAL? Select the option which lists all correct answers comma-separated.



- ○ A
- ✖ B
- ○ C
- ○ D
- ○ A, B, D
- ○ A, C
- ○ A, D
- ○ B, D
- ○ B, C, D
- ○ C, D
- ○ none

The NE555 has an output signal of 4.45 Hz with 92% duty cycle.
The CD4040 is a Ripple Counter, where the output frequency is divided by 2 every output.
So the frequency of C and D is too low. But for A, the duty cycle is inverted, and with 8% too low.
Thus, only B is correct.

Q13 (EV)

You have a powertrain composed of a battery with an internal resistance of 0.2 Ω and an OCV (Open Circuit Voltage) of 500V, an inverter with an efficiency of 97%, a single electric motor with an efficiency of 94%, a chain transmission with a gear ratio of 4 (reduction of motor speed) and an efficiency of 98% and a differential with a gear ratio of 1 and an efficiency of 96%. The vehicle is two wheel drive with a wheel radius of 0.3 m.
Consider no other losses.
At a given moment, during braking with energy recovery, the current entering the battery is 84 A and the vehicle speed is 70 km/h.
At that moment, how much torque is being produced by each wheel?

Answer in Nm and provide the value with 0 decimal places, e.g. 12.

Answer: 390

Vbat=OCV+I*R = 500 + 84*0.2 = 516.8 V
Pbat=I*Vbat = 43 411,2 W
Pground = Pbat/(product of efficiencies) = 43 411,2 / (0.97*0.94*0.98*0.96) = 50 606,3 W
Speed = 70 km/h = 70000/3600 = 19.444 m/s
ω = speed / perimeter * 2π = 19.444 / (2 * 0.3 * π) * 2π = 64,814 rad/s
Pwheel = ω*τ = Pground/2
τ = Pwheel/ω = 50 606,3 / 2 / 64,814 = 390 Nm